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FORM PTO-1390 (REV 11-98) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 551512/058

U.S. APPLICATION NO. (If known, see 37 CFR 1.5): 09/297289

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP98/03828	August 28, 1998	August 28, 1997

TITLE OF INVENTION
SPRING, MAINSPRING, HAIRSPRING, AND DRIVING MECHANISM AND TIMEPIECE BASED THEREON

APPLICANT(S) FOR DO/EO/US
Masatoshi Moteki, Fumio Takagi and Tatsuo Hara

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [ ] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [X] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [X] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [X] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [X] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information:

Form PCT/RO/101 - PCT Request and International Application as filed (Japanese)
Form PCT/RO/101 - PCT Request (English)
Form PCT/IB/346 - Notification Concerning the Filing of Amendments of the Claims
Amendments to Claims as filed with the International Bureau Under Article 19(1) (Japanese)
Amendments to Claims as filed with the International Bureau Under Article 19(1) (English)
Form PCT/IB/308 - Notice Informing the Applicant of the Communication of the International Application to the Designated Offices
Form PCT/ISA/210 - PCT International Search Report and References (Japanese)
Form PCT/ISA/210 - PCT International Search Report (English)

U.S. APPLICATION NO (if known, see 37 CFR 1 5)	INTERNATIONAL APPLICATION NO PCT/JP98/03828	ATTORNEY'S DOCKET NUMBER 5515127058

17. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

	CALCULATIONS	PTO USE ONLY
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$970.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO........ **$840.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$760.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$670.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$96.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 840.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	37 - 20 =	17	X $18.00	$ 306.00	
Independent claims	6 - 3 =	3	X $78.00	$ 234.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 1380.00	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also by filed (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$ 1380.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 1380.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 40.00	
TOTAL FEES ENCLOSED =				$ 1420.00	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of $______ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 19-4709 in the amount of $1420.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 19-4709. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

STROOCK & STROOCK & LAVAN LLP
180 Maiden Lane
New York, New York 10038
(212) 806-5400

SIGNATURE:

Lawrence Rosenthal
NAME

24,377
REGISTRATION NUMBER

Docket No.:
551512/058
LR:HMG:DMF

09/297289

28 APR 1999

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Masatoshi Moteki, et al

Examiner:

Serial No.: Not Yet Assigned

Group Art:

Filed: Concurrently Herewith

For: United Stated National Stage Application based on International Application Serial No. PCT/JP98/03828, filed August 28, 1998
For: SPRING, MAINSPRING, HAIRSPRING, AND DRIVING MECHANISM AND WATCH BASED THEREON

April 28, 1999

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
BOX PCT
Washington, D.C. 20231

Sir:

Prior to examination of this National Stage PCT application, please amend the application as follows:

Express Mail Number: EL 342 348 917 US
Date of Deposit: April 28, 1999

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to: *Assistant Commissioner for Patents, Washington, D.C. 20231.*

Name: Linda Granda-Solis
Signature: Linda Granda-Solis

825683v1

IN THE SPECIFICATION

Please amend the specification as follows:

Page 1, line 27, replace "①" with --1.--.

Page 2, line 8, replace "②" with --2.--.

Page 2, line 18, replace "③" with --3.--.

Page 3, line 20, after "mainspring" delete "L".

Page 5, line 3, change "modules" to --modulus--.

Page 6, line 10, change "modules" to --modulus--.

Page 6, line 19, change "E1" to --ε1--.

Page 8, lines 2, 3 and 16, after "mainspring" change "1" to --31--.

Page 9, line 24, after "mainspring" change "1" to --31--.

Page 10, line 11, change "wristtimepiece" to --wristwatch--.

Page 10, line 28, after "preferably insert --have--.

Page 12, line 11, after "follows" change "." to --:--.

Page 12, line 12, replace "①" with --1.--.

Page 12, line 16, replace "②" with --2.--.

Page 12, line 22, after "the" insert --second-- and delete "②".

Page 12, line 23, after "achieve" insert --what is described in paragraph number 1-- and delete "①".

Page 13, line 23, change "and" to --end--.

Page 16, line 4, change "damaged" to --affected--.

Page 16, line 6, after "300° C" insert --, i.e., the temperature--.

Page 16, line 16, replace "to simplify the" with --a simplified--.

Page 18, line 8, after "Fig. 5" insert --taken along line A-A--.

Page 18, line 10, after "Fig. 5" insert --taken along line B-B--.

Page 18, line 11, replace "Fig." With --Figs.--, replace "8" with --8A-B--, and replace "view" with --views--.

Page 18, line 27, after "Fig. 13" insert --taken along line C-C--.

Page 19, line 22, replace "anticlockwise" with --counterclockwise--.

Page 20, line 28, after "and" insert --to--.

Page 22, line 23, replace ":" with --.--.

Page 22, line 24, replace "① Since" with --First, since--.

Page 23, line 5, replace "② Because" with --Second, because--.

Page 23, line 15, replace "③ In" with --Third, in--.

Page 23, line 24, replace "④ A" with --Finally, a--.

IN THE CLAIMS

Please cancel claims 1-13 without prejudice and add new claims 14-50 as follows:

--14. A spring, said spring being formed of amorphous metal and serving as a source of power.--

--15. A spring as recited by claim 14, wherein said spring is incorporated in a substrate, said spring defining a flexure.--

--16. A spring as recited by claim 14, wherein said spring has a circular cross-section.--

--17. A spring as recited by claim 16, wherein the circular cross-section has a diameter of at least 0.05 mm.--

--18. A spring as recited by claim 14, wherein said spring has a rectangular cross-section.--

--19. A spring as recited by claim 18, wherein the rectangular cross-section has a thickness of at least 0.01 mm and a width of at least 0.05 mm.--

--20. A spring as recited by claim 14, wherein said spring is constructed from a non-magnetic material.--

--21. A spring as recited by claim 14, further comprising a plurality of amorphous metal strips laminated together.--

--22. A spring as recited by claim 21, wherein said plurality of amorphous metal strips are laminated together with a synthetic resin adhesive.--

--23. A mainspring, said mainspring being formed from an amorphous material.--

--24. A mainspring as recited by claim 23, wherein said mainspring is incorporated in a substrate, said spring defining a flexure.--

--25. A mainspring as recited by claim 23, wherein said mainspring has a circular cross-section.--

--26. A mainspring as recited by claim 25, wherein the circular cross-section has a diameter of at least 0.05 mm.--

--27. A mainspring as recited by claim 23, wherein said mainspring has a rectangular cross-section.--

--28. A mainspring as recited by claim 27, wherein the rectangular cross-section has a thickness of at least 0.01 mm and a width of at least 0.05 mm.--

--29. A mainspring as recited by claim 23, wherein said mainspring is constructed from a non-magnetic material.--

--30. A mainspring as recited by claim 23, further comprising a plurality of amorphous metal strips laminated together.--

--31. A mainspring as recited by claim 30, wherein said plurality of amorphous metal strips are laminated together with a synthetic resin adhesive.--

--32. A mainspring as recited by claim 23, wherein said mainspring defines a free-exploded S-shape.--

--33. A mainspring as recited by claim 31, wherein said mainspring includes an inner end which serves as a winding side for said mainspring, and an outer end, wherein said free-exploded S-shape has a curvature changing point where the curvature of the free-exploded shape changes, said curvature changing point being located at a point closer to said inner end than to a point midway between said inner end and said outer end.--

--34. A hairspring, said hairspring being made from an amorphous metal.--

--35. A hairspring as recited by claim 34, wherein said hairspring is incorporated in a substrate, said hairspring defining a flexure.--

--36. A hairspring as recited by claim 34, wherein said hairspring has a circular cross-section.--

--37. A hairspring as recited by claim 36, wherein the circular cross-section has a diameter of at least 0.05 mm.--

--38. A hairspring as recited by claim 34, wherein said hairspring has a rectangular cross-section.--

--39. A hairspring as recited by claim 38, wherein the rectangular cross-section has a thickness of at least 0.01 mm and a width of at least 0.05 mm.--

--40. A hairspring as recited by claim 34, wherein said hairspring is constructed from a non-magnetic material.--

--41. A timepiece comprising a mainspring, said main spring being formed from an amorphous metal.--

--42. A timepiece as recited by claim 41, wherein said mainspring defines a free-exploded S-shape.--

--43. A timepiece as recited in claim 42, wherein said mainspring includes an inner end which serves as a winding side for said mainspring, and an outer end, wherein said free-exploded S-shape has a curvature changing point where the curvature of the free-exploded shape changes, said curvature changing point being located at a point closer to said inner end than to a point midway between said inner end and said outer end.--

--44. A timepiece comprising a hairspring, said hairspring being formed of amorphous metal.--

--45. A timepiece as recited by claim 44, wherein said hairspring defines a free-exploded S-shape.--

--46. A timepiece as recited in claim 44, wherein said hairspring includes an inner end which serves as a winding side for said hairspring, and an outer end, wherein said free-exploded S-shape has a curvature changing point where the curvature of the free-exploded shape changes, said curvature changing point being located at a point closer to said inner end than to a point midway between said inner end and said outer end.--

--47. A drive mechanism comprising:

two amorphous metal mainsprings;

a plurality of barrel drums housing said two amorphous metal mainsprings; and

a train wheel, said plurality of barrel drums simultaneously engaging said train wheel, for transmitting mechanical energy from said two mainsprings.--

--48. A drive mechanism as recited in claim 47, wherein said plurality of barrel drums are phase shifted from each other when they engage said train wheel.--

--49. A time piece having a drive mechanism comprising:

two amorphous metal mainsprings;

a plurality of barrel drums housing said two amorphous metal mainsprings; and

a train wheel, said plurality of barrel drums simultaneously engaging said train wheel, for transmitting mechanical energy from said two mainsprings.--

--50. A time piece as recited in claim 48, wherein said plurality of barrel drums are phase shifted from each other when they engage said train wheel.—

REMARKS

Prior to consideration of the above-referenced application, Applicants request entry of the above amendments. This Preliminary Amendment is submitted to place the above-referenced national phase application based on international application Serial No. PCT/JP98/03828 in condition for examination. The amendments to the application provided herein add no new matter and are fully supported by the specification as filed.

Specifically, the specification has been amended to correct typographic and grammatical errors. Newly added claims 14-50 eliminate multiple dependencies from claims 1-13, and correspond directly to those claims. No new matter has been added by either the amendments to the specification or by new claims 14-50.

Early and favorable consideration of the above referenced application in light of these amendments is earnestly requested.

Respectfully submitted,

By ______________________

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11PRTS

DESCRIPTION

SPRING, MAINSPRING, HAIRSPRING, AND DRIVING MECHANISM AND TIMEPIECE BASED THEREON

Technical Field

The present invention relates to a spring used in a precision machine such as a timepiece, applicable, for example, as wielding means for fixing a crystal oscillator composing a timepiece or the like, or as a power source for a driving mechanism of a timepiece, a music box or the like.

Background Art

Various springs have conventionally been adopted in precision machines such as a timepiece and a music box. In a timepiece, for example, there are known a spring fixing a crystal oscillator of a crystal oscillating timepiece in a wielded state, a mainspring composing a power source for a driving mechanism of a timepiece, a click spring provided for preventing back-winding upon winding a mainspring, and a hairspring wielding a timed annular balance in a mechanical timepiece.

Conventional materials applicable for these springs include spring materials and mainspring materials such as carbon steel, stainless steel, a cobalt alloy, and a copper alloy. These materials have however the following problems.

① The spring fixing a crystal oscillator in a wielded state poses a problem in that the wielding force of the spring causes a shift in the pace of the crystal oscillator.

More specifically, dispersion of the spring wielding force causes a gain or a loss of the period of a 32 kHz signal issued by the crystal, and this leads to a problem of a shift of accuracy of a timepiece using this signal as a reference signal. The smallest possible dispersion of wielding force is therefore required for a spring fixing the crystal oscillator.

② In a hairspring wielding a timed annular balance forming a governor for a mechanical timepiece, a temperature change results in a change in Young's modulus which in turn causes dispersion of the wielding force, and hence a change in the oscillating period of the timed annular balance. This change in the oscillating period of the timed annular balance exerts an important effect on the accuracy of a mechanical timepiece. It is therefore desirable to adopt a hairspring material, of which Young's modulus does not change under the effect of a change in temperature.

③ Further, in the case of a mainspring serving as a power source for a driving mechanism of a timepiece or the like, a mainspring satisfying contradictory requirements of a long-time operation of the driving mechanism and downsizing of the driving mechanism is demanded. More specifically, for example, a driving mechanism of a timepiece comprises a mainspring serving as a power source, a barrel drum housing the mainspring, and a train wheel transmitting a mechanical energy of the mainspring by engaging with the barrel drum. Hands of the timepiece are rotated, via a transmitting unit such as the train wheel, by the use of the rotation force produced by the release of the

tightly wound mainspring.

The number of turns of the mainspring serving as a power source of such a driving mechanism and the output torque are in a proportional relationship. When the output torque of the mainspring is T, the number of winding runs (number of turns) of the mainspring is N, Young's modulus is E, the total length of the mainspring is L, and the mainspring is assumed to have a rectangular cross-section having a thickness t and a width b, it is known that T can be expressed by:

$$T = (Et^3b\pi/6L) \times N \quad \ldots \quad (1)$$

On the other hand, the total length L, the thickness t and the width b of the mainspring are dependent on the size of the barrel drum housing the mainspring. If the barrel drum has an inside radius R and a barrel arbor radius r, the total length L of the mainspring is determinable from the following formula:

$$L = \pi(R^2 - r^2)/2t \quad \ldots \quad (2)$$

It is thus suggested that the total length L and the thickness t of the mainspring L are in a inversely proportional relationship.

The mechanical energy accumulated in the mainspring is obtained by integrating the output torque of Equation (1) by the number of turns N, and Equation (1) is considered to be a function of the total length L and the thickness t of the mainspring. The spring energy has therefore conventionally been adjusted by controlling L and t.

This means that the maximum number of turns Nmax of the mainspring can be increased by reducing the mainspring

thickness t and increasing the mainspring total length L.

On the contrary, the value of output torque T can be increased by reducing the total length L of the mainspring, and increasing the mainspring thickness t.

As is evident from Equation (2), however, in this manner of determination, the mainspring thickness t and the total length L are limited by the volume of the housing space within the barrel drum. When adopting a mainspring operable for a long period of time, therefore, it is necessary to use a larger-sized barrel drum and a larger housing space, thus leading to a problem of impossibility to downsize the driving mechanism including the mainspring.

It was once conceived to achieve a mainspring capable of outputting a high torque with a thinner thickness t by adopting a mainspring material having a high Young's modulus. This contrivance was however limited in terms of mainspring durability since it was difficult to maintain toughness of the mainspring.

The present invention has an object to provide a spring which permits achievement of a high accuracy and stable operation of a precision machine such as a timepiece, and to provide a spring enabling, when used as power source, to operate for a long period of time, and a driving mechanism having this spring as a power source.

Disclosure of Invention

1. Specification of spring material

The spring of the present invention comprises an amorphous metal.

An amorphous metal is adopted as a spring material with a view to selecting a spring material having a large tensile stress and a small Young's modules. More specifically, comparison of a conventional mainspring material (chemical composition (wt.%): from 30 to 45% Co, from 10 to 20% Ni, 8 to 15% Cr, under 0.03% C, from 3 to 5% W, from 3 to 12% Mo, from 0.1 to 2% Ti, from 0.1 to 2% Mn, from 0.1 to 2% Si, and the balance Fe) and a spring comprising an amorphous metal reveals the following result:

	σmax (kgf/mm^2)	E (kgf/mm^2)
Conventional material	200	20,000
Amorphous spring	340	9,000-12,000

Applicable amorphous metals for the foregoing amorphous spring include, for example, Ni-Si-B, Ni-Si-Cr, Ni-B-Cr, and Co-Fe-Cr amorphous metals. Any of various amorphous metals can be adopted in response to the required performance of the spring.

When adopting a spring comprising an amorphous metal as described above, a higher allowable stress is available because of a higher maximum tensile stress of the amorphous spring, and as compared with a spring of the conventional material having the same shape, a higher wielding force is obtained: it is therefore suitable for downsizing a precision machine.

Since the spring comprises an amorphous metal, a wire or a ribbon can easily be manufactured by any of the single roll process, the dual roll process and the rotation underwater spinning process, thus permitting simplification

of the spring manufacturing process.

Further, because of a satisfactory corrosion resistance of the amorphous metal, it is possible to eliminate the necessity of rust preventive plating for some portions.

When the spring comprising an amorphous metal is used as wielding means for fixing a crystal oscillator, it is possible to prevent a gain or a loss of the signal period of the crystal oscillator for the following reason. As described above, the spring comprising an amorphous metal has a low Young's modules. As a result, the relationship between the amount of flexure ε of the spring and the wielding force F is as shown in Fig. 1: it takes the form of graph G2 having a smaller inclination than graph G1 representing a conventional material of spring. Therefore, when the spring of the conventional material giving a wielding force F0 necessary for fixing the crystal oscillator has an amount of flexure $\varepsilon 1$, and the amorphous spring has an amount of flexure $\varepsilon 2$, and if a change δ occurs in the amounts of flexure E1 and $\varepsilon 2$ of the both springs, comparison of changes df1 and df2 in the wielding force F0 reveals that the change df2 in the wielding force of the amorphous spring is smaller. By adopting the amorphous spring as wielding means for fixing the crystal oscillator, therefore, it is possible to reduce dispersion of the wielding force, minimize the shift of the period of the crystal oscillator, and thus improve accuracy of the timepiece.

If a spring comprising an amorphous material is adopted as a hairspring for wielding a time annular balance forming

a governor for a mechanical timepiece, a change in Young's modulus caused by a temperature change is smaller as compared with a usual hairspring material such as carbon steel. Upon occurrence of a change in temperature, a change in oscillating period resulting from dispersion of wielding force is slight, thus permitting improvement of a mechanical timepiece.

Further, when adopting a spring comprising an amorphous metal as a power source for a driving mechanism, i.e., in the case of a mainspring comprising an amorphous metal, achievement of long-time operation of the power source can be determined on the basis of the following concept.

More specifically, the flexure of a mainspring 31 (having a thickness t, a width b and a length L) can be approximately determined, as shown in Fig. 2, as a flexure of a cantilever supporting beam, of which the inner end 311 is rigidly connected to the barrel arbor 33, and the other outer end is left free. The flexure angle α (rad) in Fig. 2 can be expressed, when the mainspring 31 has a flexure radius r, by:

$$r = L/\alpha \quad \ldots \quad (3)$$

The number of turns of the mainspring can be expressed, on the other hand, by means of the above-mentioned flexure angle α as follows:

$$N = \alpha/2\pi \quad \ldots \quad (4)$$

The above-mentioned equation (1) can therefore be transformed, from equations (3) and (4), into:

$$T = (bt^3E/12L) \times \alpha \quad \ldots \quad (5)$$

An energy U accumulated by the flexure of the

mainspring 31 can be calculated by integrating a bending moment acting on the mainspring 1, i.e., an output torque of the mainspring 1 as to α:

$$U = \int T d\alpha = \int (bt^3E/12L) \times \alpha d\alpha$$

$$= (bt^3E/24L) \times \alpha^2 \quad \ldots \quad (6)$$

Consequently, the maximum energy Umax capable of being stored in a mainspring having a length L can be expressed, if the maximum flexure angle of the mainspring 31 is αmax, as follows:

$$Umax = (bt^3E/24L) \times \alpha max^2 \quad \ldots \quad (7)$$

The bending stress σ acting on the mainspring 31 is expressed as a function of the bending moment acting on the mainspring 31, i.e., the output torque T that the mainspring 31 in a flexure state can output. When the displacement in the thickness direction from the neutral axis A of the mainspring 1 is y, and the geometrical moment of inertia of the mainspring 31 is Iz, then the bending stress σ is expressed as:

$$\sigma = T \times y/Iz \quad \ldots \quad (8)$$

Therefore, the maximum bending stress σb in the tensile direction acting on the upper surface of the mainspring 31 in Fig. 2 calculated, from equation (8):

$$\sigma b = T \cdot (t/2)Iz \quad \ldots \quad (9)$$

The cross-sectional area of the mainspring 31, forming a rectangular shape with a thickness t and a width b, calculated as follows:

$$Iz = bt^3/12 \quad \ldots \quad (10)$$

and from equations (9) and (10), this is expressed as:

$$T = (bt^2/6) \times \sigma b \quad \ldots \quad (11)$$

Consequently, T is expressed, from equations (1) and (11), as follows:

$$T = (Et^3 b\pi/6L) \times N = (bt^2/6) \times \sigma b \quad \ldots \quad (12)$$

The maximum number of turns Nmax giving α max in equation (7) is, from equation (4):

$$N\ max = \alpha max/2\pi \quad \ldots \quad (13)$$

Therefore, the following relationship can be derived:

$$\alpha max = 2L\sigma b/Et \quad \ldots \quad (14)$$

It is therefore suggested that αmax is determined by the maximum bending stress σb in the tensile direction of the mainspring 31, i.e., the maximum tensile stress σmax of the mainspring material used for the mainspring 31, and the above-mentioned equation (7) is calculated as follows:

$$Umax = (bt^3E/24L) \times (2L\sigma max/Et)^2$$
$$= (btL/6) \times (\sigma max^2/E) \quad \ldots \quad (15)$$

Equation (15) reveals that the maximum energy Umax stored in the mainspring 31 in Fig. 2 varies not only with the thickness t, the width b and the length L of the mainspring 31, but also with the maximum tensile stress σmax and Young's modulus E of the material forming the mainspring 31.

In order to increase the energy Umax stored in the mainspring, therefore, it is desirable to adopt, for the mainspring 1, a material having a high maximum tensile stress σmax and a low Young's modulus. In other words, when adopting the foregoing amorphous spring having σmax = 340 (kgf/mm^2) and E = 9,000 to 12,000 (kgf/mm^2) as a material for the mainspring 31, it is known from equation (15) that an amount of energy 4.8 to 6.4 times as large as that available

in the conventional art can be stored.

By adopting an amorphous mainspring as a power source for the driving mechanism of a timepiece or a music box, therefore, it is possible to improve the energy volume density capable of being stored in the mainspring without the need to modify the geometry of the other parts such as the barrel drum. It is thus possible to achieve a long-time operation of the power source for the driving mechanism while permitting downsizing, and therefore, the amorphous mainspring is particularly suitable as a power source for the driving mechanism of a wristtimepiece requiring utmost efforts for downsizing.

When a spring comprising the amorphous metal as described above is used as a hairspring or a mainspring, it should preferably be a mainspring comprising a non-magnetic material. If the mainspring comprises a non-magnetic material, magnetic resistance is improved. Even when the mainspring is attracted by a magnetic field, properties of the mainspring are never deteriorated. When a spring comprising an amorphous metal is used for a fixed spring or a click spring for a crystal oscillator, the spring, if comprising a non-magnetic material, permits improvement of magnetic resistance, and the wielding force of the spring is never affected by a magnetic field or the like, as in the aforementioned case.

2. Optimum shape of spring comprising amorphous metal

A spring comprising an amorphous metal should preferably a cross-sectional shape of a circle having a diameter of at least 0.05 mm, or a rectangle having a size

of at least a thickness of 0.01 mm x a width of 0.05 mm.

More specifically, when the spring has such a cross-sectional shape, a sufficient wielding force is available. It is therefore applicable as fixing means of a crystal oscillator, a hairspring wielding a timed annular balance serving a governor for a mechanical timepiece, or a mainspring serving as a power source for a driving mechanism.

A spring comprising an amorphous metal should preferably have a substrate or a main plate into which it is incorporated with an initial flexure.

Presence of an initial flexure prevents a play or a shift of the spring from occurring even incorporated in a substrate or a main plate. When there is an initial flexure, it is possible to apply a load from beginning. In a spring of the conventional material, a high Young's modulus results in a reduced allowance to the allowable stress. In the spring comprising the amorphous metal, in contrast, having a low Young's modulus, a sufficient margin of the allowable stress is ensured even when the initial flexure applies a load.

Further, when the aforementioned spring comprising the amorphous metal is used as a mainspring serving as a power source for a driving mechanism, this mainspring has a free-exploded shape of an S, and the curvature changing point where the curving direction of the free-exploded shape changes should preferably be located on the inner end side from the middle point between an inner end on the winding side and the other end which is an outer end.

The free-exploded shape of a mainspring means an

exploded shape available when releasing the mainspring from the constraint, such as the shape of the mainspring taken out from the barrel drum.

In the free-exploded shape of the mainspring comprising a conventional material, as in graph G shown in Fig. 3, the shape is formed into an S closest to an ideal curve in which the curvature changing point (where the radius of curvature ρ is infinite, and the curving direction of the mainspring changes) is provided at the middle point C between the inner end and the outer end of the mainspring. The reason is as follows.

① To previously reforming the mainspring in a direction counter to the winding direction to store as much as possible energy in the mainspring upon tightening the mainspring; and

② To prevent breakage of the mainspring caused by stress concentration by causing the bending stress to uniformly act on the entire mainspring.

On the other hand, as described above, the amorphous mainspring has a smaller Young's modulus than in the conventional mainspring material, and this alleviates the limitation imposed by the reason ② mentioned above, permitting reforming solely to achieve ① above.

More specifically, an optimum free-exploded shape of the amorphous mainspring is determined as follows.

If the spiral shape of a mainspring housed in a barrel drum upon tightly winding is assumed to be an Archimedes' spiral, and polar coordinates r and θ and adopted, r is expressed as:

$$r = (t/2\pi) \cdot \theta \quad \ldots \quad (16)$$

(where, t: mainspring thickness)

The conditions giving an ideal curve permitting available stress concentration over the entire mainspring is obtained from the following equation when assuming that the bending moment acting on the mainspring is M, bending rigidity of the mainspring is B, the radius of curvature of the mainspring in the free-exploded shape is $\rho 0$, and the radius of curvature of the outer periphery portion of the mainspring upon tightening is $\rho 1$:

$$(1/\rho 1) - (1/\rho 0) = M/B = \text{constant} \quad \ldots \quad (17)$$

The conditions for achieving the maximum elastic energy as stored in the mainspring as a whole are provided by the following equation on the assumption that the maximum amount of elastic strain of the mainspring is εmax:

$$B/M = t/4\varepsilon max \quad \ldots \quad (18)$$

When the mainspring length as measured along the curve from the winding start center is L', the following relationship stands:

$$1/\rho 1 = (\pi/tL')^{1/2} \quad \ldots \quad (19)$$

Therefore, from equations (17) and (19):

$$1/\rho 0 = (\pi/tL')^{1/2} - M/B \quad \ldots \quad (20)$$

Because the inner and of the mainspring is actually wound on the barrel arbor, the actual mainspring length L is as follows on the assumption of a barrel arbor radius γ:

$$L = L' - \pi r^2/t \quad \ldots \quad (21)$$

The metal equation for the ideal curve shape is as expressed by equation (22):

$$\rho 0 = 2(\pi/t) \times (B/M)^3 \times (1/L) + B/M \quad \ldots \quad (22)$$

Therefore, the radius of curvature $\sigma 0$ in the free-exploded shape at the maximum energy stored in the mainspring can be expressed, from equations (18) and (22), as follows:

$$\rho 0 = 2(\pi/t) \times (t/4\varepsilon max)^3 \times (1/L) + t/4\varepsilon max \quad \ldots \quad (23)$$

With $\varepsilon max = 0.02$, the pitch of the spiral shape of the ideal curve becomes completely smaller than the thickness t of the mainspring. Actually, therefore, a shape close to $\varepsilon max = 0.02$ would be used in place of the result of calculation.

Representation of equation (23) in Fig. 3 described above would take the form of graph G4: it suggests the possibility of forming a calculated curvature changing point on the inner side from graph G3 of a mainspring made of the conventional material.

With the amorphous mainspring, it is therefore possible to reform the entire length of the mainspring in a direction counter to the winding direction, and thus to increase the stored energy upon tightly winding.

The foregoing equation (1) is a basic equation for theoretical calculation, and equation (22) is as well a theoretical equation determinable from this basic equation. In practice, it is necessary to take account of occurrence of frictions between mainsprings and between the mainspring and the barrel drum and the necessity of a winding margin for connecting the mainspring and the barrel arbor.

Therefore, when the correction coefficient of frictions is K1, and the number of turns for winding the mainspring

around the barrel arbor, the relationship between the number of turns N and the output torque T for the mainspring of the conventional material is:

$$T = K1 \cdot (Ebt^3\pi/6L) \times (N - No) \quad \ldots \quad (24)$$

Therefore, as shown in Fig. 4, as compared with the output torque property G6 of the mainspring of the conventional material, the output torque property G5 of the amorphous mainspring exhibits, though with the same number of turns, a smaller inclination of the curve and a smaller change in torque caused by a change in the number of turns. Because the same number of torque leads to a higher torque, the period of endurance increases, and the driving mechanism can be operated for a longer period of time.

3. Formation of amorphous mainspring in optimum shape

When using the above-mentioned spring made of the amorphous metal as a mainspring, an amorphous mainspring should preferably be manufactured by integrally laminating two, three or more amorphous metal sheets, since it is difficult to manufacture a mainspring having a thickness t of over 50 μm from a single sheet.

More specifically, because amorphous metal sheets are laminated, as is known from equations (1), (22) and (23), it is possible to freely set an amorphous mainspring thickness t in response to the required performance including an output torque.

When integrally laminating the sheets, the plurality of amorphous metal sheets should preferably be bonded with a synthetic resin adhesive.

The synthetic resin adhesive permits achievement of

integral lamination of the plurality of amorphous metal sheets at a relatively low temperature. Properties of the amorphous metal therefore never change, and the aforementioned features of the amorphous mainsprings are never damaged.

More particularly, it suffices to adopt an adhesive which sets at a temperature of up to about 300°C at which properties of the amorphous metal change. An epoxy-based adhesive, for example, sets at about 100°C, and properties of the amorphous metal never change at this temperature.

Because the adhesive easily deforms before completion of setting, reforming of the foregoing amorphous mainspring can be easily accomplished by winding the same on a jig or the like.

Further, it is not necessary to apply a separate heat treatment for reforming as in the conventional mainspring, thus enabling to simplify the manufacturing process of the mainspring. Reforming of the amorphous mainspring can be accomplished also by spot-welding the inner end portion, the curvature changing point portion and the outer end portion of each of the plurality of amorphous metal sheets. Effects similar to those mentioned above are available also by using the thus integrally laminated spring as a fixing spring or a click spring of a crystal oscillator.

4. Driving mechanism using amorphous mainspring

The driving mechanism using the mainspring of the present invention is based on a mainspring comprising the above-mentioned amorphous mainspring and a train wheel for transmitting mechanical energy of this mainspring. It has a

plurality of amorphous mainsprings and a plurality of barrel drums for housing these mainsprings, wherein the plurality of barrel drums simultaneously engage with the train wheel.

More specifically, because the plurality of barrel drums housing the amorphous mainsprings are simultaneously engaged with the train wheel, an output torque composed of superposed torque outputs from the plurality of barrel drums acts on the train wheel, thus making it possible to cause a large torque to act on the train wheel, and hence to operate the driving mechanism with a high torque.

In the configuration as described above, phases of engagement of the plurality of barrel drums with the train wheel should preferably shift from each other.

Because the phases of engagement are staggered, a change in torque produced by engagement between a barrel drum with the train wheel can be offset by engagement with another barrel drum. It is thus possible to inhibit dispersion of torque transmitted from the entire barrel drums to the train wheel and to operate the driving mechanism smoothly.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph illustrating the relationship between strain and wielding force for describing operations of the present invention;

Fig. 2 is a schematic view for explaining operations of the present invention;

Fig. 3 is a graph illustrating the position of the curvature changing point as derived from the relationship

between the mainspring length and the radius of curvature;

Fig. 4 is a graph illustrating the relationship between the number of turns and the output torque;

Fig. 5 is a plan view illustrating a driving mechanism using an amorphous mainspring of a first embodiment of the invention;

Fig. 6 is a sectional view of the driving mechanism of the first embodiment shown in Fig. 5;

Fig. 7 is another sectional view of the driving mechanism of the first embodiment shown in Fig. 5;

Fig. 8 is a plan view illustrating a mainspring housed in a barrel drum in the first embodiment shown in Fig. 5;

Fig. 9 is a sectional view of the mainspring of the embodiment shown in Fig. 5 cut along the thickness direction thereof;

Fig. 10 is a plan view illustrating a free-exploded shape of the mainspring in the embodiment shown in Fig. 5;

Fig. 11 is a partially cutaway plan view illustrating a driving mechanism of a second embodiment of the invention;

Fig. 12 is a partially cutaway plan view illustrating engagement between barrel drums and a train wheel in the second embodiment shown in Fig. 11;

Fig. 13 is a plan view illustrating the structure of a timed hairspring of a third embodiment of the invention;

Fig. 14 is a sectional view illustrating the structure of the timed hairspring of the third embodiment in the third embodiment shown in Fig. 13; and

Fig. 15 is a side view illustrating a fixing structure of a crystal oscillator of a fourth embodiment of the

invention.

Best Mode for Carrying Out the Invention

Embodiments of the present invention will now be described with reference to the drawings.

A first embodiment relates to a driving mechanism using the spring of the invention as a mainspring. Fig. 5 is a plan view illustrating a driving mechanism of a electronically controlled mechanical timepiece using the amorphous mainspring of the first embodiment of the invention; and Figs. 6 and 7 are sectional views thereof.

The driving mechanism 1 of the electronically controlled mechanical timepiece is provided with a barrel drum 30 having an amorphous mainspring 31, a barrel gear 32, a barrel arbor 33 and a barrel cover 34. The amorphous mainspring 31 has an outer end connected to the barrel gear 32 and an inner end fixed to the barrel arbor 33. The barrel arbor 33 is supported by a main plate 2 and a train wheel bridge 3, and secured by a ratchet wheel screw 5 to as to rotate integrally with a ratchet wheel 4.

The ratchet wheel 4 engages with a click 6 so as to rotate clockwise but not anticlockwise. Because the method of winding the amorphous mainspring 31 by rotating the ratchet wheel 4 clockwise is the same as in automatic winding or manual winding of a mechanical timepiece, description thereof is omitted here.

Rotation of the barrel gear 32 is increased to seven times as high and transmitted to a center wheel 7, then sequentially, 6.4 times to a third wheel 8, 9.375 times to a

second wheel 9, three times to a fifth wheel 10, ten times to a sixth wheel 11, and ten times to a rotor 12: the rotation speed is thus increased to 126,000 times as high, and these wheel gears compose a train wheel.

A cannon pinion 7a is secured to the center wheel 7, a minute hand 13, to the cannon pinion 7a, and a second hand 14, to the second wheel 9. In order to rotate the center wheel at 1 rph, and the second wheel 9 at 1 rpm, therefore, it suffices to perform control so as to rotate the rotor 12 at 5 rps. At this point, the barrel gear 1b rotates at 1/7 rph.

This electronically controlled mechanical timepiece has a generator 20 comprising a rotor 12, a stator 15, and a coil block 16. The rotor 12 comprises a rotor magnet 12a, a rotor pinion 12b and a rotor inertia disk 12c. The rotor inertia disk is for minimizing dispersion of revolutions of the rotor 12 against dispersion of driving torque from the barrel drum 30. The stator 15 is formed by winding 40,000 turns of stator coil 15b onto a stator body 15a.

The coil block 16 is made by winding 110,000 turns of coil 16b onto a magnetic core 16a. The stator 15a and the magnetic core 15b are made of PC permalloy or the like. The stator coil 15b and the coil 16 are connected in series so as to give an output voltage added with respective generated voltage.

AC output generated by the generator 20 as described above is fed to a control circuit incorporated with a view to controlling speed adjustment and turn-on/off of the driving mechanism 1, although not shown in Figs. 5 to 7.

Then, the internal structure of the aforementioned barrel drum 30 will be described with reference to Fig. 8.

Fig. 8(A) illustrates a state in which the aforesaid amorphous mainspring 31 is tightly wound in the barrel drum 30; and Fig. 8(B) shows a state after the amorphous mainspring 31 is released in the barrel drum.

The amorphous mainspring 31 has a size comprising a width b of 1 mm, a thickness t of 0.1 mm, and a total length L of 300 mm.

As described above, the amorphous mainspring 31 has the inner end 311 wound onto the barrel arbor 33, and the outer end 312 connected and fixed to the inner surface of the barrel arbor.

When the barrel drum 30 is rotated by an external force relative to the barrel arbor 33 in the state of Fig. 8(B), the amorphous mainspring 31 is tightly wound. When, after tight winding, the mainspring is released from constraint of the barrel drum 30, the barrel drum 30 rotates along with rewinding of the amorphous spring 31. The train wheel including the center wheel 7 described above is rotated by the barrel gear 32 formed on the outer periphery of the barrel drum 30, leading to operation of the minute hand 13 and the second hand 14.

The amorphous mainspring 31 is formed by integrally laminating a plurality of amorphous metal sheets 313 each having a thickness of 50 μm as shown in Fig. 9, and the individual amorphous metal sheets 313 are bonded with each other with an epoxy-based adhesive 314.

The amorphous mainspring 31 removed from the barrel

drum 30 is reformed in a direction counter to the winding direction onto the barrel arbor 33, and has substantially an S-shaped free-exploded shape in a plan view.

The curvature changing point 315 where the curving direction changes is formed near the inner end 311. The portion between the curvature changing point 315 and an inner end 311 is used for securing the amorphous mainspring 31 to the barrel arbor 33.

When manufacturing such an amorphous mainspring 31, the amorphous metal sheet 313 is first fabricated into a width and a length necessary as a power source for the driving mechanism 1.

The individual amorphous metal sheets 313 are bonded to each other with the use of an epoxy-based adhesive 314 to ensure a thickness t (0.1 mm) necessary for the amorphous mainspring 31.

Finally, before setting of the epoxy-based adhesive 314, the amorphous mainspring 31 is reformed by winding it onto a round rod or the like, and the epoxy-based adhesive 314 is caused to set.

According to the amorphous mainspring 31 of the first embodiment as described above, the following advantages are available:

① Since the amorphous mainspring 31 is adopted as the power source for the driving mechanism 1, it is possible to operate the driving mechanism 1 for a long period of time while maintaining downsizing of the driving mechanism 1.

When a conventional mainspring is incorporated in the aforementioned driving mechanism 1, operation stops in 40

hours from the tight winding. When the amorphous mainspring 31 is incorporated, in contrast, operation is discontinued in 45 hours from the tight winding, resulting in an increase in operable hours by about 10%.

② Because the curvature changing point 315 can be set at a position near the inner end 311, reforming can be applied over substantially the entire length of the amorphous mainspring 31, thus making it possible to increase mechanical energy stored by the amorphous mainspring 31, and further extend operating hours of the driving mechanism 1.

The amorphous mainspring 31 has only a slight dispersion of torque. When adopting it as a power source of a mechanical timepiece, therefore, it is possible to improve driving accuracy.

③ In the conventional art, a mainspring having a prescribed thickness has been obtained by repeatedly rolling a bulk material.

The above-mentioned amorphous mainspring 31 can easily be manufactured into a wire, a ribbon or the like by the single-roll process, the dual-roll process or the rotation underwater spinning process. It is therefore possible to simplify the manufacturing process of the amorphous mainspring.

④ A plurality of amorphous metal sheets 313 are integrally laminated with the use of an epoxy-based adhesive 314. A heating process is not therefore necessary for forming the amorphous mainspring 31, and properties of the amorphous metal are never damaged.

Since reforming can be effected before setting of the

adhesive, reforming can be accomplished easily by, for example, winding the mainspring 31 onto a jig or the like.

A driving mechanism using the amorphous mainspring of a second embodiment of the invention will now be described. For the same or similar components as those already explained, description will be omitted or simplified hereafter.

In the driving mechanism 1 of the aforementioned first embodiment, only one amorphous mainspring 31 housed in the barrel drum 30 has served as the power source for operating the driving mechanism 1.

The driving mechanism 101 of the second embodiment differs from that of the first embodiment, as shown in Fig. 11, in that the driving mechanism 101 has two barrel drums, and amorphous mainsprings 31 housed therein serve as power sources for the driving mechanism 101.

Barrel gears 32 (not shown in Fig. 11) formed on the outer peripheries of two barrel drums 30 simultaneously engage with a base gear 71 of a center wheel 7 of the driving mechanism 101.

The two barrel drums 30 rotate in the same direction around respective barrel arbors 33, and a torque 2T comprising the sum of values of output torque T of the individual amorphous mainsprings 31 acts on the center wheel 7.

For the barrel gears 32 engaging with the center wheel 7, as shown in Fig. 12, engagement phases are different between the barrel gear 32 to the left and the barrel gear 32 to the right. At the moment when the left barrel gear 32

comes into contact with the center wheel 7 at point B1, the right barrel gear is about to leave the center wheel 7 at point B2.

Such a difference in phase depends upon the relative positions of the barrel arbors 33. As is known from Fig. 11, the engagement phase can be adjusted in response to the angle β between the rotational center of the center wheel 7 and the barrel arbor 33.

According to the driving mechanism 101 using the amorphous mainspring of the second embodiment as described above, the following advantages are available in addition to those described above as to the first embodiment. Because the two barrel drums 30 housing the amorphous mainsprings 31 are simultaneously engaged with the center wheel 7 forming the train wheel, it is possible to cause the center wheel 7 to rotate by superposing values of output torque T of the respective barrel drums 30, and thus to operate the driving mechanism 101 at a high output torque 2T.

Because the phases of the barrel gears 32 engaging with the center wheel 7 are staggered, operation of the driving mechanism 101 can be smoothed by inhibiting changes in the transmitted torque through alleviation of torque dispersion produced from a state of engagement between, for example, the left barrel drum 30 and the center wheel 7 in Fig. 12 by means of the state of engagement with the other right barrel drum 30.

A third embodiment of the invention will now be described. In the third embodiment, the spring made of the amorphous metal of the invention is used as a hairspring for

wielding a timed annular balance forming a governor of a mechanical timepiece. A balance hairspring 400 serving as a governor in this embodiment comprises, among others, a balance arbor 410, an annular balance 420, a double roller 430, a collet 440, a stud 450, and a regulator 460, as shown in Figs. 13 and 14.

The annular balance 420, the double roller 430, and the collet 440 are secured to the balance arbor 410 so as to permit integrated rotation. A hairspring 470 is a non-magnetic spring made of an amorphous alloy, has an inner peripheral end fixed to the collet 440, and an outer end fixed to the stud 450. The regulator 460 comprises, among others, a regulator pin 461 and a regulator key 462, and the outermost peripheral portion of the hairspring 470 passes between the regulator pin 461 and the regulator key 462.

In the balance hairspring 400, when the annular balance 420 rotates around the balance arbor 410 as the axis, the collet 440 rotates also along with this. The wielding force of the hairspring 470 acts on the annular balance 420. Upon achievement of a balance between this wielding force and inertia of the hairspring 470, rotation of the annular balance 420 stops, and the wielding force of the hairspring 470 causes the annular balance 420 to rotate in the reverse direction. That is, the annular balance 420 repeats oscillation with the balance arbor 410 as the axis. The oscillation period of the annular balance 420 can be changed by finely adjusting the position of the regulator key 462. This oscillation period T varies also with the inertia moment J of the rotating portion such as the annular balance

as well as with material properties of the hairspring 470. When the hairspring 470 is assumed to have a width b, a thickness t, a spring length L, and a Young's modulus E of the hairspring, T is expressed by the following equation (25):

$$T = 2\pi\sqrt{\frac{12JL}{Ebt^3}} \quad \ldots \quad (25)$$

According to the third embodiment of the invention as described above, the following advantages are available.

Because the hairspring 470 is made of an amorphous metal, changes in Young's modulus E caused by a change in temperature are slight, with small changes in the oscillation period of the balance hairspring 400 as expressed by equation (25), thus making it possible to improve accuracy of a mechanical timepiece having a governor including the balance hairspring 400.

Since the hairspring 470 is made of a non-magnetic amorphous metal, magnetic resistance is improved, and even when the hairspring 470 is attracted by an external magnetic field or the like, mainspring properties are never impaired.

A fourth embodiment of the invention will now be described. The fourth embodiment uses a spring made of the amorphous metal of the invention as a spring for fixing a crystal oscillator of a crystal oscillator type timepiece in a wielded state.

More specifically, as shown in Fig. 15, the crystal oscillator 500 comprises, among others, a vacuum capsule 501, and a tuning fork type oscillator 502 housed in this vacuum

capsule 501. An oscillation circuit is formed by a terminal 503 provided at an end of the vacuum capsule 501 and electrically connected to a circuit board 510.

The crystal oscillator 500 as described above is arranged on a main plate 520, and fixed thereto while being wielded by a screw 530 and a fixing spring 540 made of an amorphous metal in a direction of being pressed against the main plate 520.

According to the fourth embodiment of the invention, the following advantages are available. The fixing spring 530 made of an amorphous metal has a low Young's modulus. The relationship between the amount of flexure of the fixing spring 530 and the wielding force therefore takes the form of graph G2 showing a smaller inclination than in graph G1 of the spring made of the conventional material as shown in Fig. 1. Even upon occurrence of a change in the amount of flexure of the fixing spring 530, therefore, a change in the wielding force becomes smaller, thus permitting reduction of the shift of period of the crystal oscillator, and hence, improvement of accuracy of the crystal oscillator type timepiece.

The present invention is not limited to the aforementioned embodiments, but includes also the following variants.

While, in the first embodiment described above, the amorphous mainspring 31 has been used as the power source of the driving mechanism 1 for the electronically controlled mechanical timepiece, application of the invention is not limited to this, but the amorphous mainspring may be used

for a driving mechanism of an ordinary mechanical timepiece having a control system comprising a governor and an escapement.

In the first embodiment described above, the amorphous mainspring 31 has been used as the power source for the driving mechanism 1 of a timepiece. Application of the present invention is not however limited to this, but the amorphous mainspring may be used as a power source for a driving mechanism of a music box or the like.

Further, while the amorphous mainsprings 31 have been integrally laminated by the use of the adhesive 314, integration may be accomplished through spot welding of the inner end 311, the outer end 312 and the curvature changing point 315. Reforming of the amorphous mainspring can be conducted to some extent in this manner simultaneously with integral lamination.

In the second embodiment mentioned above, the two barrel drums 30 have been engaged with the center wheel 7 forming the train wheel. More than two barrel drums 30 may however be engaged. The number of barrel drums 30 may be appropriately selected in response to the energy stored in the amorphous mainspring and the energy required as a power source of the driving mechanism.

In the fourth embodiment described above, the spring made of an amorphous metal has been used as the fixing spring 530 for fixing the crystal oscillator 500, but application is not limited to this. More specifically, the spring forming the click 6 engaging with the ratchet wheel 4 in the first embodiment may be made of an amorphous metal.

The click is provided for preventing back-winding when winding the mainspring in the barrel drum, and the spring functioning at this point is the click spring. The click spring is therefore subjected to a repeated load by a number of teeth of engagement with the ratchet wheel in engagement with the click during winding of the mainspring, and this number of times reaches several tens of thousand or even several hundreds of thousand. When such a repeated load is applied, the allowable stress of the click spring should be set to less than 1/2 of the maximum stress. By using a spring made of an amorphous metal as such a click spring, therefore, it is possible to set a high allowable stress, with smaller dispersion of the wielding force, and the click is favorable also as a click spring.

In addition, the detailed structure and shape for the application of the present invention may be other structure or shape within a range in which the other objects of the invention is achievable.

Industrial Applicability

The spring, the mainspring, the hairspring and the driving mechanism and the timepiece using these springs of the invention is suitably applicable as a power source of a driving mechanism for a timepiece, a music box or the like, as a spring for fixing a crystal oscillator in a crystal oscillator type timepiece or the like, as a hairspring for wielding a timed annular balance of a mechanical timepiece, and as a click spring for preventing back-winding upon winding a mainspring in a barrel drum.

AH 19

WHAT IS CLAIMED IS:

1. A spring comprising an amorphous metal to serve as a power source.

2. A spring according to claim 1, wherein said spring is incorporated with an initial flexure into a substrate or a main plate.

3. A spring according to claim 1 or 2, wherein said spring has a circular cross-section with a diameter of at least 0.05 mm, or a rectangular cross-section with a thickness of 0.01 mm and a width of at least 0.05 mm.

4. A spring according to claim 1, wherein said spring comprises a non-magnetic material.

5. A spring according to claim 1, wherein said spring is formed by integrally laminating a plurality of amorphous metal sheets.

6. A spring according to claim 5, wherein said plurality of amorphous metal sheets are integrally laminated by means of a synthetic-resin-based adhesive.

7. A mainspring made of a spring according to any one of claims 1 to 6.

8. A mainspring according to claim 7, wherein:

the mainspring has an S-shaped free exploded shape, with a curvature changing point where there is a change in the curving direction of the free exploded shape, formed inside an intermediate point between an inside end serving as the winding side end and an outside end serving as the other end of said inside end.

9. A hairspring comprising a spring according to any one of claims 1 to 4.

10. A timepiece using a mainspring or a hairspring according to any one of claims 7 to 9.

11. A driving mechanism using a mainspring comprising a mainspring according to any one of claims 7 and 8, and a train wheel transmitting mechanical energy of said mainspring, comprising:

two or more mainsprings and a plurality of barrel drums for housing these mainsprings;

wherein said train wheels are engaged simultaneously with said plurality of barrel drums.

12. A driving mechanism using the mainspring according to claim 11, wherein:

said plurality of barrel drums are engaged with said train wheels at phases shifting from each other.

13. A timepiece using a driving mechanism utilizing mainsprings according to claim 11 or 12.

ABSTRACT

A mainspring used as a power source for a driving mechanism is made of an amorphous metal sheet, and has an S-shaped free-exploded shape. The curvature changing point where the curving direction of the free-exploded shape changes is formed on the inner end side of a middle point between the inner end on the winding side and the outer end serving as the other end of the inner end. Because of the high tensile stress and a low Young's modulus, the amorphous metal permits increase in mechanical energy stored in the mainspring.

FIG. 1

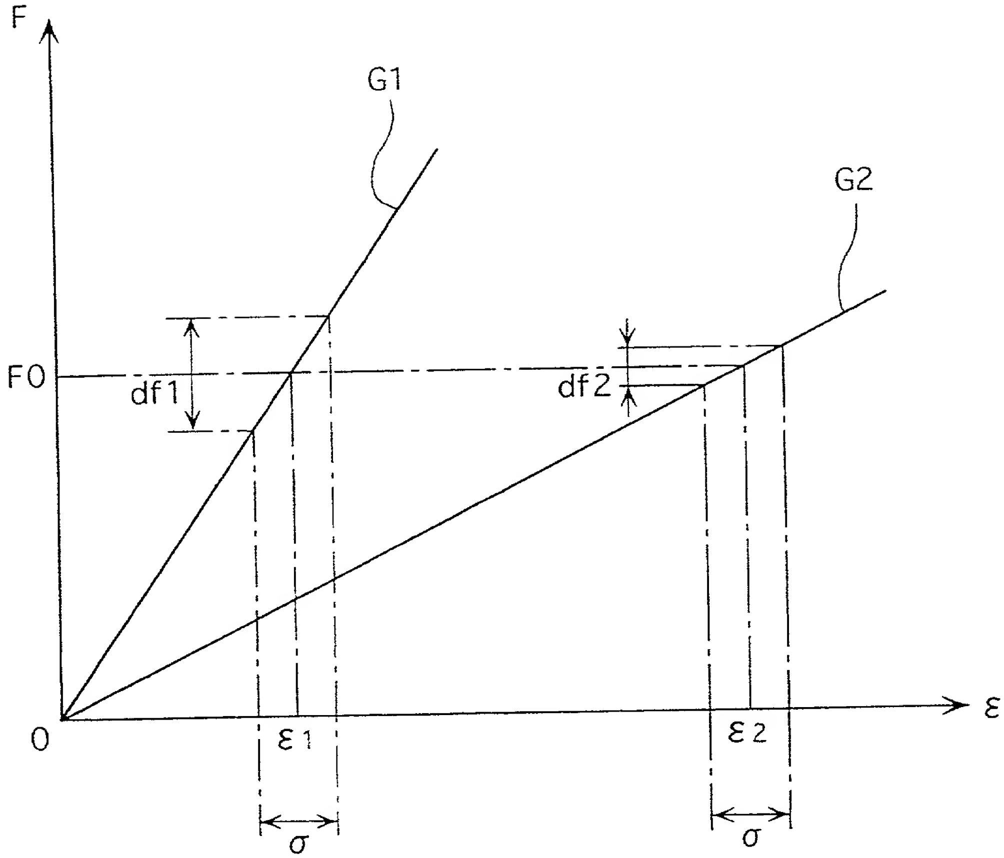


FIG. 2

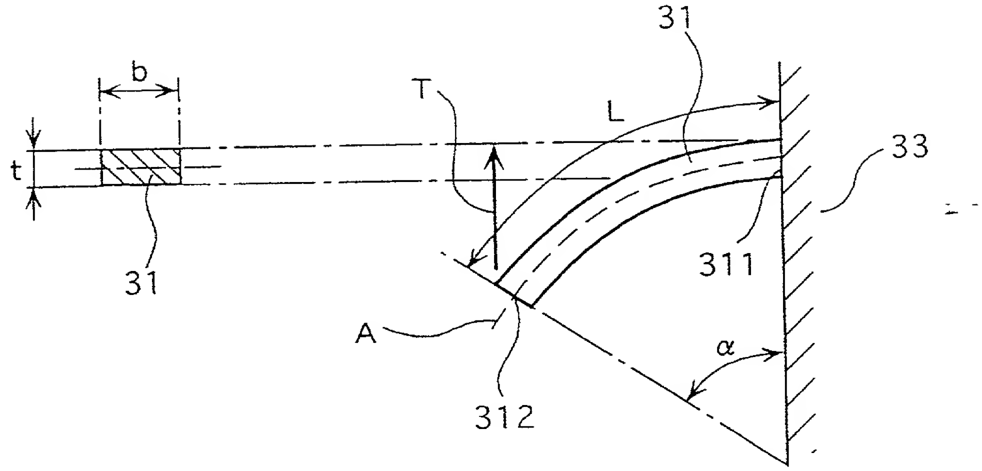

b
t
31
T
L
31
33
311
A
312
α

FIG. 3

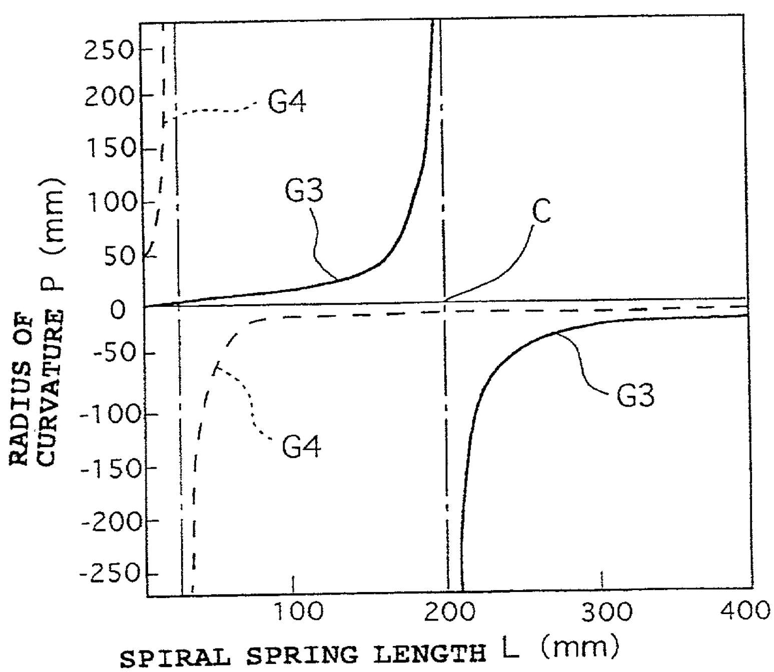

250
200
150
100
50
0
-50
-100
-150
-200
-250
G4
G3
C
G3
G4
RADIUS OF CURVATURE P (mm)
100
200
300
400
SPIRAL SPRING LENGTH L (mm)

FIG. 4

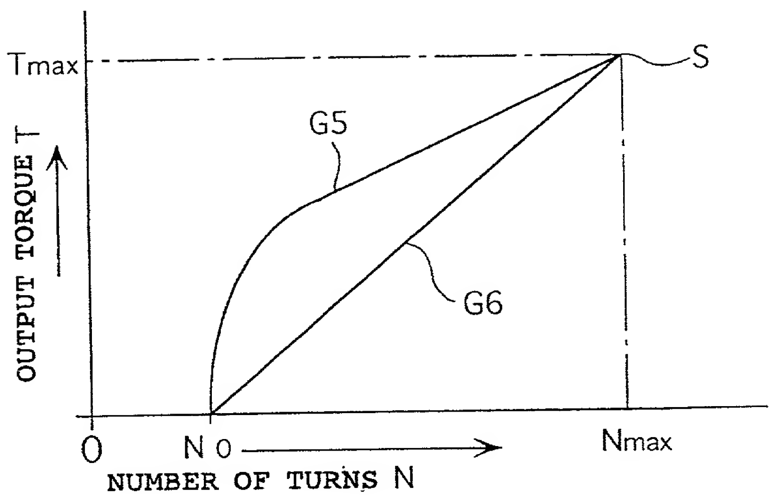
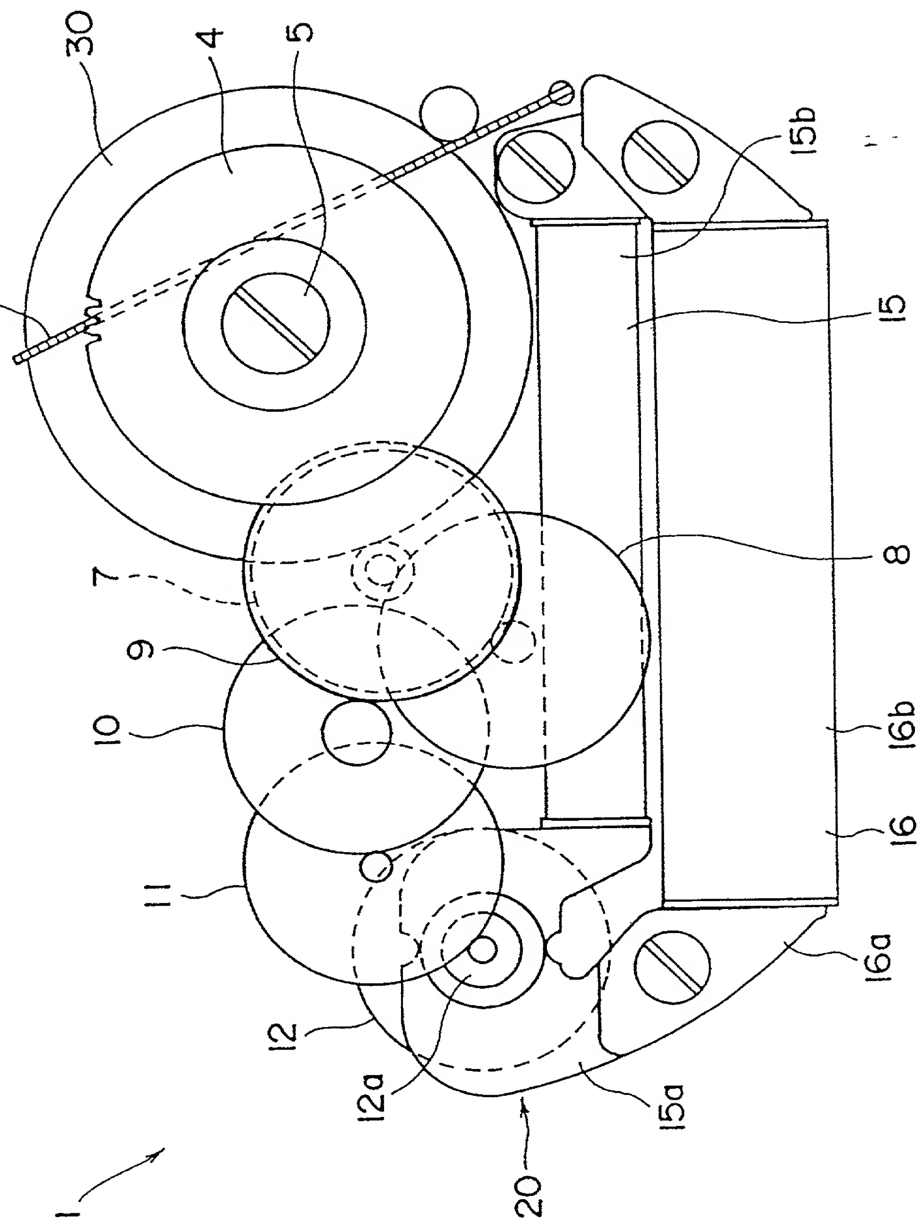


FIG. 5



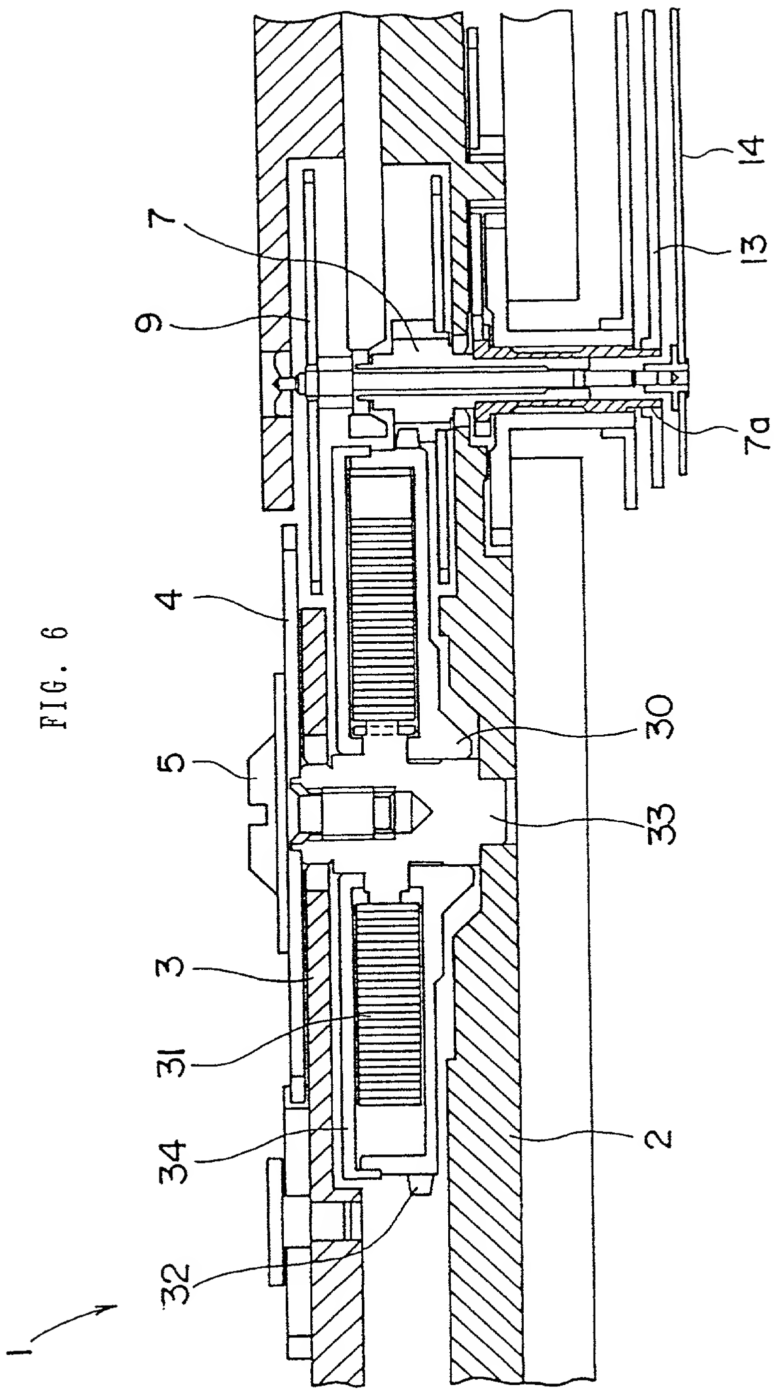


FIG. 6

FIG. 7

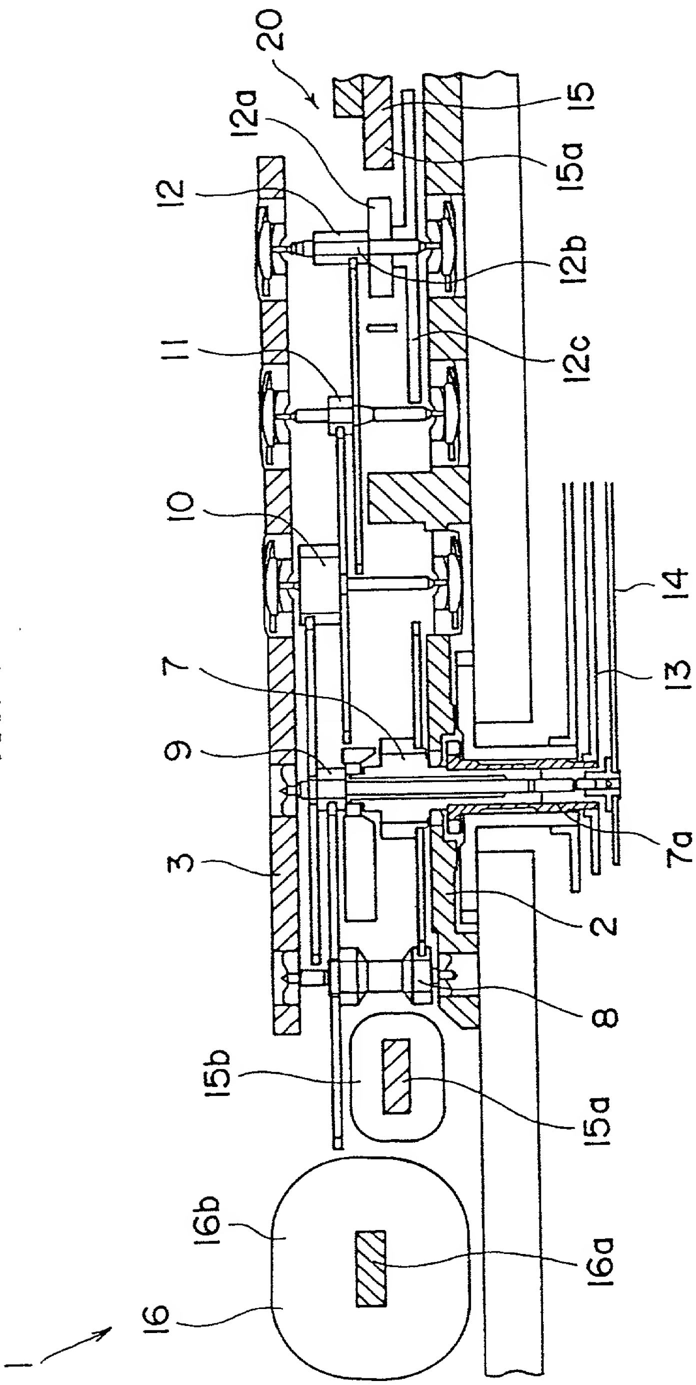


FIG. 8

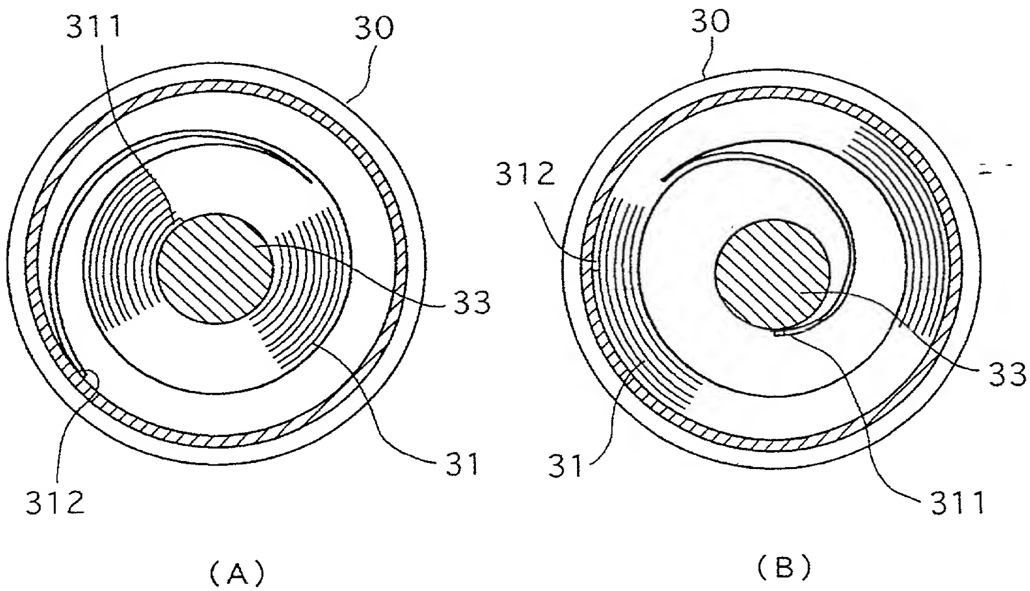


FIG.9

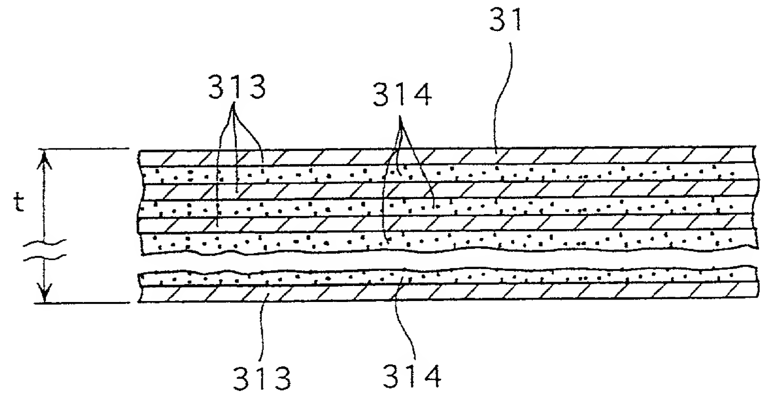


FIG. 10

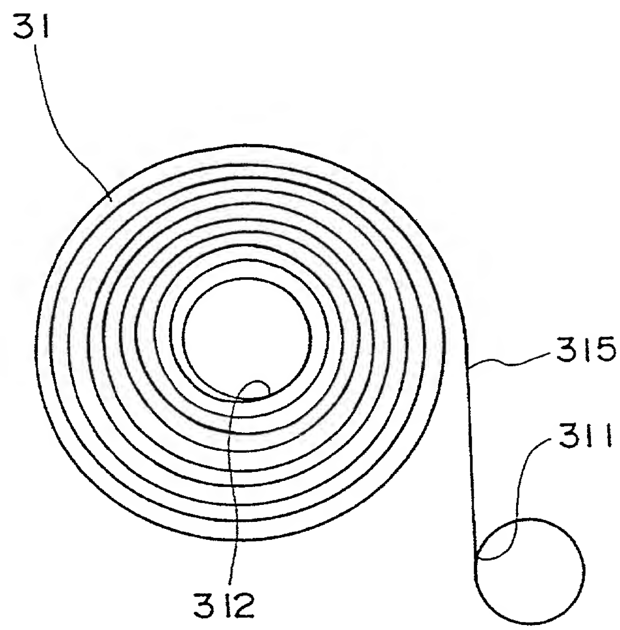


FIG. 11

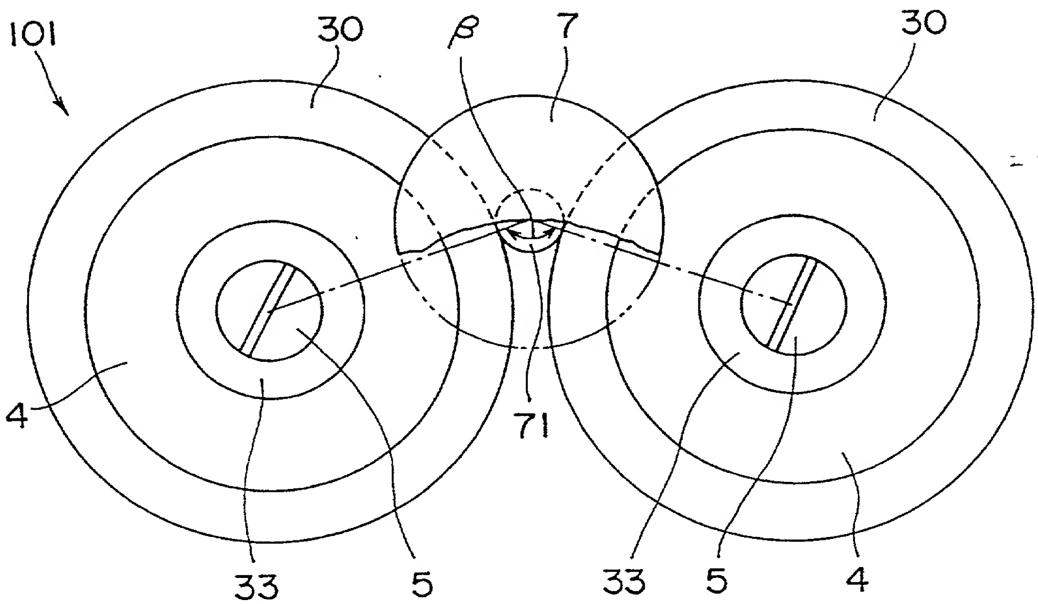


FIG. 12

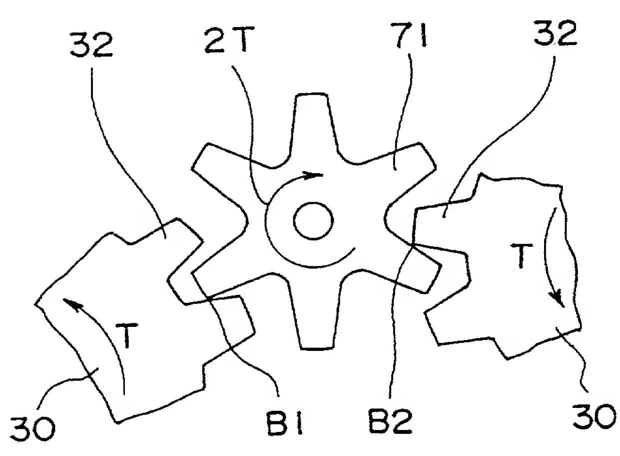


FIG. 13

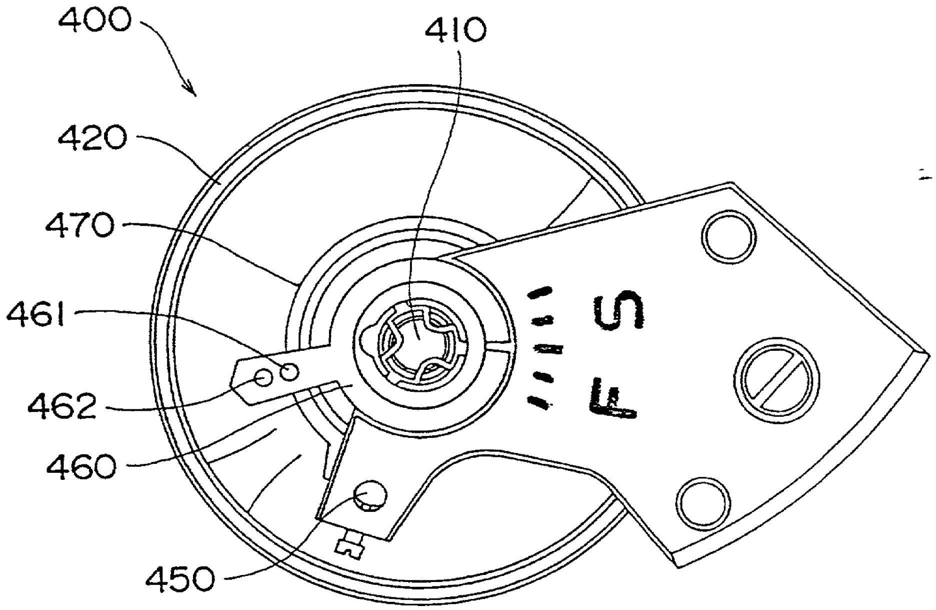
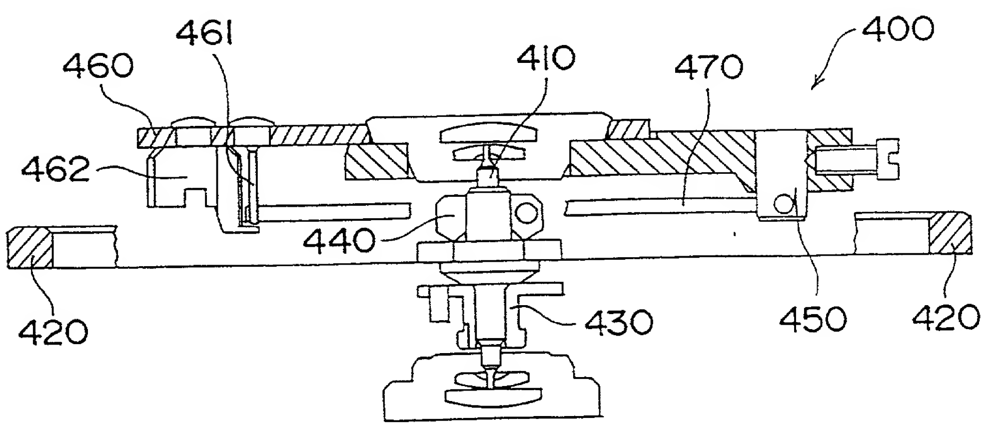

400
410
420
470
461
462
460
450
S
F

FIG. 14


461
460
410
470
400
462
440
420
430
450
420

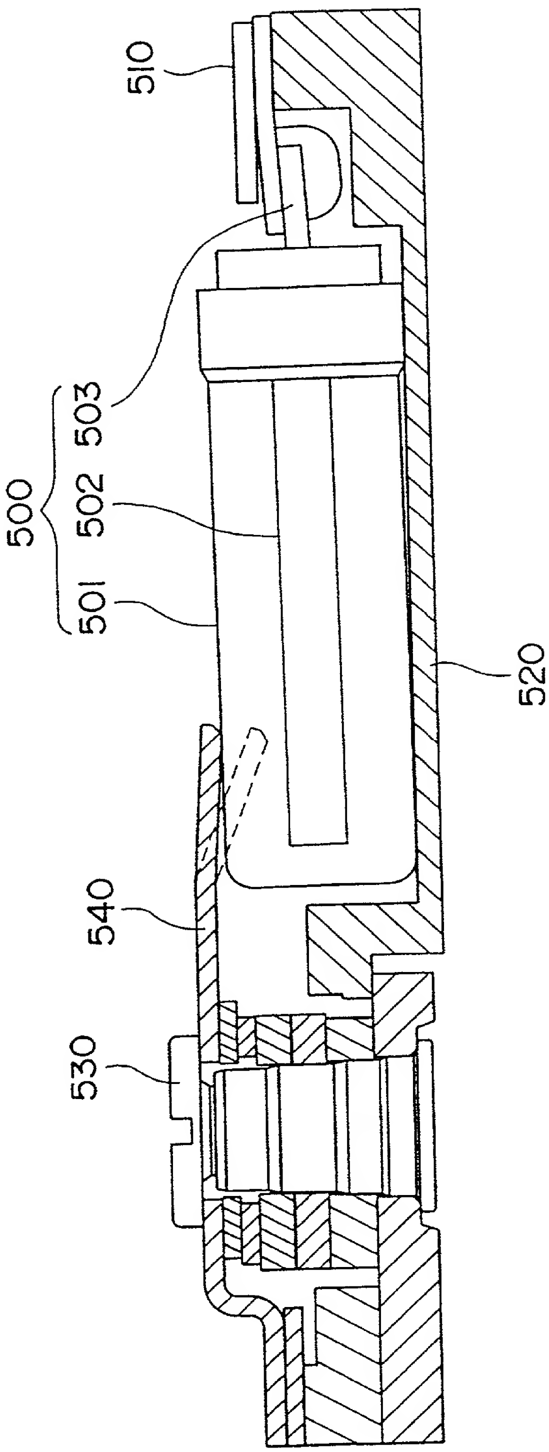


FIG. 15

Seiko Epson Ref. No.: F004094US00 | Attorney's Ref. No.: 551512/058

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は、下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

バネ、ゼンマイ、ヒゲゼンマイ、これらを利用した駆動機構、および時計

SPRING, MAINSPRING, HAIRSPRING, AND DRIVING MECHANISM AND WATCH BASED THEREON

上記発明の明細書（下記の欄で×印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

☐ 1998年8月28日に提出され、米国出願番号または特許協定条約 国際出願番号をPCT/JP98/03828 とし、（該当する場合） _____ に訂正されました。

☐ was filed on August 28, 1998 as United States Application Number or PCT International Application Number PCT/JP98/03828 and was amended on _____ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第３７編第１条５６項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

PTO/SB/106 (8-96)
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I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Not Claimed 優先権主張なし
9-216775	Japan	11/August/1997	☐
			☐

私は、第３５編米国法典１１９条(e)項に基いて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119 (e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Application No.) (出願番号)	(Filing Date) (出願日)

私は下記の米国法典第３５編１２０条に基いて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約３６５条(c)に基づく権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第３５編１１２条第１項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第３７編１章５６項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365 (c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application:

(Application No.) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)
PCT/JP98/03570	11/August/1998	Pending

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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(日本語宣言書)

委任状： 私は、下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。（弁護士、または代理人の氏名及び登録番号を明記のこと） Harold I. Kaplan (Reg. 16,958) Lawrence Rosenthal (Reg. 24,377) Steven B. Pokotilow (Reg. 26,405) Howard M. Gitten (Reg. 32,138) Matthew W. Siegal, (Reg. 32,941)	POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)* 5 Harold I. Kaplan (Reg. 16,958) Lawrence Rosenthal (Reg. 24,377) Steven B. Pokotilow (Reg. 26,405) Howard M. Gitten (Reg. 32,138) Matthew W. Siegal, (Reg. 32,941)
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国籍 日本	Citizenship Japan
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Japanese Language Declaration
(日本語宣言書)

委任状： 私は、下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。（弁護士、または代理人の氏名及び登録番号を明記のこと） Harold I. Kaplan (Reg. 16,958) Lawrence Rosenthal (Reg. 24,377) Steven B. Pokotilow (Reg. 26,405) Howard M. Gitten (Reg. 32,138) Matthew W. Siegal, (Reg. 32,941)	POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)* Harold I. Kaplan (Reg. 16,958) Lawrence Rosenthal (Reg. 24,377) Steven B. Pokotilow (Reg. 26,405) Howard M. Gitten (Reg. 32,138) Matthew W. Siegal, (Reg. 32,941)
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第三共同発明者の署名 日付 原 辰男 1999年3月31日	Third inventor's signature Date Tatsuo Hara 3/31/99
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国籍 日本	Citizenship Japan
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第四共同発明者の署名 日付	Fourth inventor's signature Date
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国籍	Citizenship
私書箱	Post Office Address
（第五以降の共同発明者についても同様に記載し、署名をすること）	(Supply similar information and signature for fifth and subsequent joint inventors.)